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<p>(21) International Application Number: <b>PCT/GB99/03581</b></p> <p>(22) International Filing Date: <b>29 October 1999 (29.10.99)</b></p> <p>(30) Priority Data: 9823669.8                    30 October 1998 (30.10.98)                    GB</p> <p>(71) Applicant (<i>for all designated States except US</i>): SERCK HEAT TRANSFER LIMITED [GB/GB]; Warwick Road, Birmingham B11 2QY (GB).</p> <p>(72) Inventor; and</p> <p>(75) Inventor/Applicant (<i>for US only</i>): ATKINSON, George [GB/GB]; 167 Ulverley Green Road, Solihull B92 8AA (GB).</p> <p>(74) Agent: MURGITROYD &amp; COMPANY; 373 Scotland Street, Glasgow G5 8QA (GB).</p>		<p>(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).</p> <p>Published  <i>With international search report.</i>  <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i></p>	
<p>(54) Title: EXHAUST GAS COOLER</p> <p>(57) Abstract</p> <p>An exhaust gas cooler for reducing the temperature of exhaust gases from internal combustion engines, comprising an external tube (20) extending between two tube plates (30a, 30b) or end walls and defining a coolant chamber (31), coolant inlet and outlet means (33, 34) communicating with the coolant chamber, and a plurality of internal tubes (38) extending between the end walls and arranged to carry the exhaust gas through the coolant chamber. The external tube (20) has a cross-sectional shape which has a height (H) in the major axis which is greater than its width (W) in the minor axis perpendicular to the major axis, preferably oval, or comprising two semi-circles (21, 22) connected by common straight line tangents (23, 24) parallel to the major axis. Such a cross-sectional shape means that the exterior tube (20) has a planar face (23, 24) which simplifies the fitting of mounting brackets and placement within an engine compartment.</p>			

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1      **Exhaust Gas Cooler**

2

3      This invention relates to an exhaust gas cooler for  
4      reducing the temperature of exhaust gases from internal  
5      combustion engines. In particular the invention  
6      relates to an exhaust gas cooler in which a coolant is  
7      passed around passages through which the exhaust gas  
8      travels.

9

10     Figs. 1a to 1c show a known exhaust gas cooler. This  
11    prior art cooler comprises a circular tube 1 which has  
12    tapered ends 2 which serve as entry 3 and exit 4  
13    orifices for exhaust gases. The orifices are provided  
14    with flange plates 10 for connection to exhaust pipes.  
15    The ends of the tube are sealed by circular tube plates  
16    5 which define a coolant chamber inside the tube. Each  
17    tube plate 5 has a number of circular holes 6 arranged  
18    through it. The holes 6 in each tube plate 5 are  
19    connected by a number of small diameter tubes 7 which  
20    are sealed at one end to the first tube plate and at  
21    the other end to the second tube plate. Exhaust gases  
22    flow into the entry orifice 3, along the inside of the  
23    small diameter tubes 7 and out of the exit orifice 4.  
24    The exterior of the tube is provided with entry and  
25    exit nozzles 8, 9 which communicate with the coolant

1       chamber for the supply of coolant liquid. A bracket 11  
2       is fixed to the tube for mounting the exhaust gas  
3       cooler.

4

5       Similar prior art exhaust gas coolers are known for  
6       example from US Patent No 4,685,292. In all the prior  
7       art coolers the tubes which carry the exhaust gases are  
8       arranged within a cooling chamber of circular cross-  
9       section. This results in exhaust gas coolers which are  
10      bulky and inefficient in their use of space and do not  
11      fit easily within the frequently cramped engine layout.  
12      It is an object of the present invention to provide an  
13      exhaust gas cooler which is more compact in shape and  
14      yet provides flow characteristics comparable or  
15      superior to prior art gas coolers.

16

17     According to a first aspect of the present invention  
18     there is provided an exhaust gas cooler comprising:  
19       an external tube having first and second end walls  
20       within said tube, said external tube and end walls  
21       defining a coolant chamber between said end walls and  
22       first and second exhaust gas chambers outside said  
23       first and second end walls respectively,  
24       coolant inlet and outlet means communicating with  
25       said coolant chamber,  
26       a plurality of internal tubes extending from said  
27       first end wall to said second end wall and arranged  
28       such that the interior of each internal tube  
29       communicates with said first and second exhaust gas  
30       chambers, and  
31       exhaust gas inlet and outlet means communicating  
32       with said first and second exhaust gas chambers  
33       respectively,  
34       wherein the external tube has a cross-sectional shape  
35       which has a height in the major axis which is greater  
36       than its width in the minor axis perpendicular to the

1 major axis.

2

3 Preferably the cross-sectional shape of the external  
4 tube is substantially oval, most preferably it  
5 comprises two semi-circles connected by common straight  
6 line tangents parallel to the major axis. Such a  
7 cross-sectional shape means that the exterior tube has  
8 a planar face which simplifies the fitting of mounting  
9 brackets and placement within an engine compartment.  
10 An oval shape offers advantages over rectangular cross-  
11 sectional shapes, since the tube is less prone to  
12 cracking, and sharp re-entrant angles in the tube are  
13 avoided, reducing stress concentration.

14

15 Preferably the internal tubes are circular in cross-  
16 section. It has been found that circular tubes are  
17 less prone to clogging with particles carried by the  
18 exhaust gases than rectangular tubes, because they do  
19 not present internal corners in which particulate  
20 matter can collect.

21

22 Preferably the internal tubes are arranged in a  
23 hexagonal close packed arrangement, such that each  
24 internal tube is spaced by the same spacing from its  
25 closest neighbouring internal tubes. Preferably the  
26 spacing is less than 2 mm, most preferably less than 1  
27 mm. Preferably the spacing is between 10% and 20% of  
28 the diameter of the tubes.

29

30 Preferably the exhaust gas cooler is made from  
31 stainless steel.

32

33 Preferably each of the exhaust gas inlet and outlet  
34 means comprises a flange plate adapted to connect to a  
35 corresponding flange plate on a connecting exhaust pipe  
36 and having an aperture therein to permit the through

1 flow of exhaust gases. Preferably each of said first  
2 and second exhaust gas chambers is further defined by a  
3 tapering cylindrical member extending from said  
4 aperture to said external tube.

5

6 Preferably the coolant inlet and outlet means comprise  
7 tubular pipes adapted to be connected to a coolant  
8 hose, most preferably extending substantially in the  
9 plane containing the longitudinal axis of the external  
10 tube and the major axis of the cross-section of the  
11 external tube. Preferably the coolant inlet means is  
12 located adjacent to one of the first and second end  
13 walls and the coolant outlet means is located adjacent  
14 to the other of the first and second end walls.  
15 Preferably the coolant inlet and outlet means extend  
16 from opposite sides of the external tube.

17

18 Preferably a longitudinally extending portion of the  
19 coolant chamber adjacent to each of the coolant inlet  
20 and outlet means has no internal tubes extending  
21 therethrough, such that it forms a coolant passage  
22 having an unobstructed area. This may be achieved by  
23 omitting a row of internal tubes from the close-packed  
24 arrangement at the top and bottom of the external tube.  
25 Preferably the unobstructed area has a minimum  
26 transverse dimension greater than the diameter of an  
27 internal tube. Preferably the unobstructed area of  
28 each passage extends over at least 10% of the internal  
29 height of the external tube, most preferably at least  
30 15%.

31

32 An embodiment of the invention will now be described,  
33 by way of example only, with reference to the  
34 accompanying figures, where:

35

36 Figs. 1a, 1b, and 1c are a side elevation, a partial

1 sectional view on line A-A, and an end elevation of a  
2 prior art exhaust gas cooler;  
3  
4 Fig. 2 is a side elevation of an exhaust gas cooler  
5 according to a first aspect of the invention;  
6  
7 Fig. 3 is an end elevation of the device of Fig. 2; and  
8  
9 Fig. 4 is a sectional view on line B-B of the device of  
10 Fig. 2.

11  
12 Referring to Figs. 2 to 4 there is shown an exhaust gas  
13 cooler according to the invention. The cooler  
14 comprises an external cylindrical tube 20 whose cross-  
15 section comprises two semi-circular portions 21, 22  
16 connected by two tangential portions 23, 24. At each  
17 end of the tube are fixed tapered cap portions 25a, 25b  
18 which are adapted to fit over the end of the tube and  
19 be fastened by suitable means such as welding. At the  
20 narrow end of the tapered cap portion 25a, 25b is a  
21 flange plate 26 provided with two holes 27 for  
22 attachment to a corresponding flange plate (not shown)  
23 in order to secure the cooler to an exhaust pipe or  
24 line (not shown). The flange plates 26 also each  
25 contain a larger hole which serves as entry 28 or exit  
26 orifices for exhaust gases.

27  
28 The ends of the tube 20 are sealed internally by two  
29 oval tube plates 30a, 30b, whose shape corresponds to  
30 the internal profile of the tube 20. The volume  
31 bounded by the tube 20 and plates 30a, 30b forms a  
32 coolant chamber 31 inside the tube. Each volume  
33 bounded by the tube cap 25a, 25b and the respective  
34 plate 30a, 30b forms an exhaust gas chamber 39a, 39b  
35 outside the coolant chamber 31 inside the tube. Each  
36 tube plate 30a, 30b has 37 circular holes 32 arranged

1 through it. The holes 32 are arranged in a close  
2 hexagonal packing (CHP) pattern as shown in Fig. 4 in 9  
3 rows of 3, 4 or 5 holes. The holes 32 in each tube  
4 plate 30a, 30b are connected by 37 small diameter tubes  
5 38 which are sealed at one end to the first tube plate  
6 30a and at the other end to the second tube plate 30b.

7

8 It has been found that a CHP pattern maximises the flow  
9 efficiency, while the particular arrangement of Fig. 4,  
10 in which the three principal axes are arranged  
11 perpendicular to and at 30° to the major axis 40 of the  
12 tube 20 provides an optimum means of packing the  
13 interior tubes within the exterior tube.

14

15 Exhaust gases flow into the entry orifice 28, along the  
16 inside of the small diameter tubes 38 and out of the  
17 exit orifice 29. The tubes 38 have a diameter of  
18 between 5 and 8 mm, usually about 6.5 mm. The spacing  
19 between the tubes is about 1 mm or less, so the tube  
20 plate 30a does not present a significant obstruction to  
21 flow of the exhaust gases.

22

23 Arranged at a first end of the exterior tube is a  
24 cooling water inlet pipe 33 whose longitudinal axis is  
25 in the same plane as the longitudinal axis 50 and the  
26 major axis 40 of the exterior cylinder 20. In this way  
27 the hose connections (not shown) will not extend  
28 outside the envelope defined by the width W of the  
29 exterior tube 20. Similarly at the second end of the  
30 exterior tube 20 is a cooling water outlet pipe 34  
31 whose axis is in the same plane as that of the inlet  
32 pipe 33. The inlet and outlet pipes 33, 34 each  
33 communicate with the coolant chamber 31 for the supply  
34 of coolant liquid. As coolant passes from the inlet 33  
35 to the outlet 34 and exhaust gases pass along the small  
36 diameter tubes 38, heat transfer takes place from the

1 exhaust gas via the surfaces of the small diameter  
2 tubes 38 to the cooling water.

3

4 The inlet 33 and outlet 34 join the exterior tube at  
5 opposite ends of the tube. In the embodiment  
6 illustrated both the inlet and outlet pipes 33, 34  
7 incorporate a 90° bend, so that the hose connections to  
8 the ends 35 of the pipes 33, 34 may be made parallel to  
9 the longitudinal axis 50 of the tube. It is to be  
10 understood that either of the inlet or outlet pipes 33,  
11 34 may be straight so that the hose connections to the  
12 ends 35 may be made perpendicular to the longitudinal  
13 axis 50 of the tube, or that either of the inlet or  
14 outlet pipes 33, 34 may incorporate a bend of an  
15 intermediate angle less than 90°. Either of the inlet  
16 or outlet pipes 33, 34 may be reversed so that the open  
17 end 35 faces towards the centre of the exhaust gas  
18 cooler, instead of facing away from the centre of the  
19 exhaust gas cooler as shown in Fig. 2.

20

21 A mounting plate 45 is provided on one side of the  
22 exhaust gas cooler, to enable the cooler to be secured  
23 within an engine compartment. In the embodiment shown  
24 the mounting plate has three leg portions 46 formed by  
25 double bending of the plate. These serve to space the  
26 exhaust gas cooler from the surface to which it is  
27 mounted. Each leg portion 46 has a mounting hole 47  
28 for a bolt or similar fastener.

29

30 The oval shape of the apparatus enables the exhaust gas  
31 cooler of the invention to fit into much tighter spaces  
32 in the engine compartment than prior art coolers, while  
33 maintaining the benefits of closely packed tubes  
34 forming the cooling core. The layout of the tubes in  
35 the cooler according to the invention is novel while  
36 still maximising the efficiency of the gas and coolant

1 flow. The cooler is highly resistant to corrosion due  
2 to its stainless steel construction, and very robust  
3 due to the absence of sharp corners on the exterior  
4 tube. The flow patterns achieved in testing have shown  
5 that the arrangement provides a high resistance to  
6 clogging from soot particles.

7

8 Although the invention shows a close packing  
9 arrangement with 37 tubes, giving the same flow area as  
10 prior art tubes, it is to be understood that other  
11 arrangements are possible. For example additional rows  
12 of tubes can be added, increasing the height H, without  
13 increasing the width W of the exterior tube 20. In a  
14 particular embodiment the top and bottom rows 60, 61 of  
15 tubes may be omitted, which in effect provides enlarged  
16 passages 62, 63 for coolant water at the top and bottom  
17 of the coolant chamber. This arrangement has been  
18 found to provide particularly advantageous flow  
19 characteristics and exhaust gas cooler performance.

20

21 These and other modifications and improvements can be  
22 incorporated without departing from the scope of the  
23 invention.

## 1        CLAIMS

2

3        1. An exhaust gas cooler comprising:  
4              an external tube (20) having first and second end  
5              walls (30a, 30b) within said tube, said external tube  
6              and end walls defining a coolant chamber (31) between  
7              said end walls and first and second exhaust gas  
8              chambers (39a, 39b) outside said first and second end  
9              walls (30a, 30b) respectively,

10             coolant inlet (33) and outlet (34) means  
11             communicating with said coolant chamber (31),

12             a plurality of internal tubes (38) extending from  
13             said first end wall (30) to said second end wall (30)  
14             and arranged such that the interior of each internal  
15             tube (38) communicates with said first and second  
16             exhaust gas chambers (39a, 39b), and

17             exhaust gas inlet and outlet means (28, 29)  
18             communicating with said first and second exhaust gas  
19             chambers (39a, 39b) respectively,

20             wherein the external tube (20) has a cross-sectional  
21             shape which has a height (H) in the major axis (40)  
22             which is greater than its width (W) in the minor axis  
23             (41) perpendicular to the major axis.

24

25        2. An exhaust gas cooler according to Claim 1,  
26             wherein the cross-sectional shape of the external tube  
27             (20) is substantially oval.

28

29        3. An exhaust gas cooler according to Claim 1,  
30             wherein the cross-sectional shape of the external tube  
31             (20) comprises two semi-circles (21, 22) connected by  
32             common straight line tangents (23, 24) parallel to the  
33             major axis (40).

34

35        4. An exhaust gas cooler according to any preceding  
36             claim, wherein the internal tubes (38) are circular in

1 cross-section.

2

3 5. An exhaust gas cooler according to any preceding  
4 claim, wherein the internal tubes (38) are arranged in  
5 a hexagonal close packed arrangement, such that each  
6 internal tube (38) is spaced by the same spacing from  
7 its closest neighbouring internal tubes.

8

9 6. An exhaust gas cooler according to claim 5,  
10 wherein the spacing between adjacent internal tubes  
11 (38) is less than 2 mm.

12

13 7. An exhaust gas cooler according to claim 5 or 6,  
14 wherein the spacing between adjacent internal tubes  
15 (38) is between 10% and 20% of the diameter of the  
16 tubes.

17

18 8. An exhaust gas cooler according to any preceding  
19 claim, wherein the exhaust gas cooler is made from  
20 stainless steel.

21

22 9. An exhaust gas cooler according to any preceding  
23 claim, wherein each of the exhaust gas inlet (28) and  
24 outlet (29) means comprises a flange plate (26) adapted  
25 to connect to a corresponding flange plate on a  
26 connecting exhaust pipe and having an aperture therein  
27 to permit the through flow of exhaust gases.

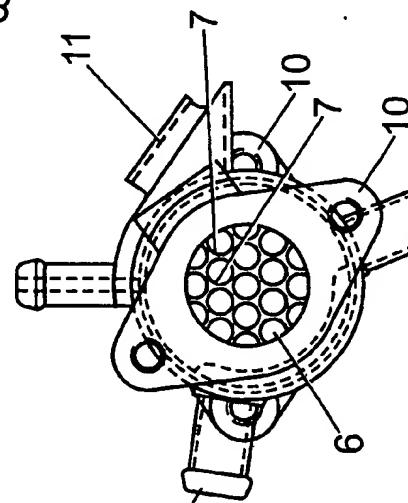
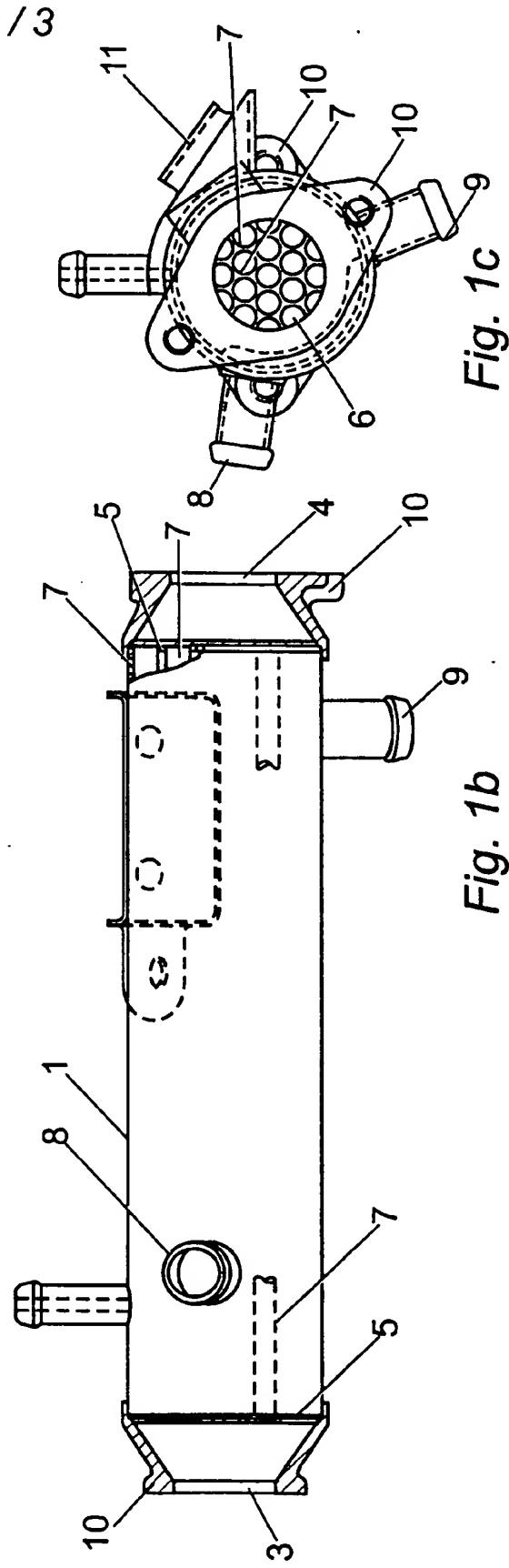
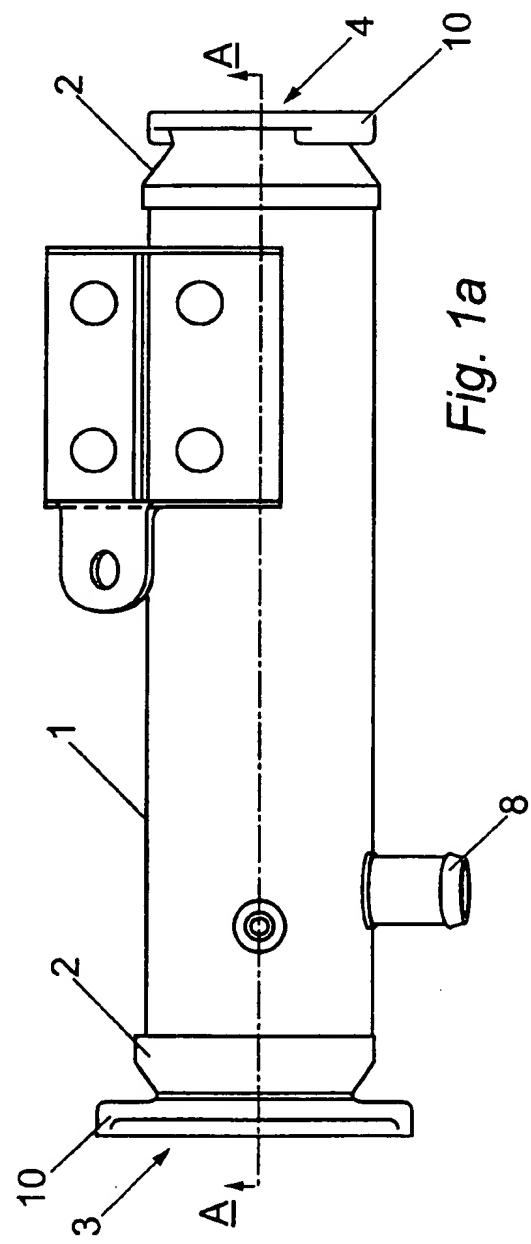
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29 10. An exhaust gas cooler according to any preceding  
30 claim, wherein the coolant inlet (33) and outlet (34)  
31 means comprise tubular pipes adapted to be connected to  
32 a coolant hose and extending substantially in the plane  
33 containing the longitudinal axis (50) of the external  
34 tube and the major axis (40) of the cross-section of  
35 the external tube.

36

- 1       11. An exhaust gas cooler according to Claim 10,  
2       wherein the coolant inlet means (33) is located  
3       adjacent to one of the first and second end walls (30a,  
4       30b) and the coolant outlet means (34) is located  
5       adjacent to the other of the first and second end walls  
6       (30a, 30b).
- 7
- 8       12. An exhaust gas cooler according to Claim 10 or 11,  
9       wherein the coolant inlet means (33) is located at one  
10      side of the external tube (2) on the major axis (40)  
11      and the coolant outlet means (33) is located on the  
12      diametrically opposite side of the external tube (2) on  
13      the major axis (40).
- 14
- 15      13. An exhaust gas cooler according to any preceding  
16      claim, wherein each of said first and second exhaust  
17      gas chambers (39a, 39b) is further defined by a  
18      tapering cylindrical member (25) extending from said  
19      aperture to said external tube.
- 20
- 21      14. An exhaust gas cooler according to any preceding  
22      claim, wherein a longitudinally extending portion of  
23      the coolant chamber (31) adjacent to the coolant inlet  
24      means (33) has no internal tubes (38) extending  
25      therethrough, such that it forms a coolant passage (63)  
26      having an unobstructed area.
- 27
- 28      15. An exhaust gas cooler according to any preceding  
29      claim, wherein a longitudinally extending portion of  
30      the coolant chamber (31) adjacent to the coolant outlet  
31      means (34) has no internal tubes (38) extending  
32      therethrough, such that it forms a coolant passage (62)  
33      having an unobstructed area.
- 34
- 35      16. An exhaust gas cooler according to claim 14 or 15,  
36      wherein the unobstructed area has a minimum transverse

- 1 dimension greater than the diameter of an internal tube
- 2 (38).



2 / 3

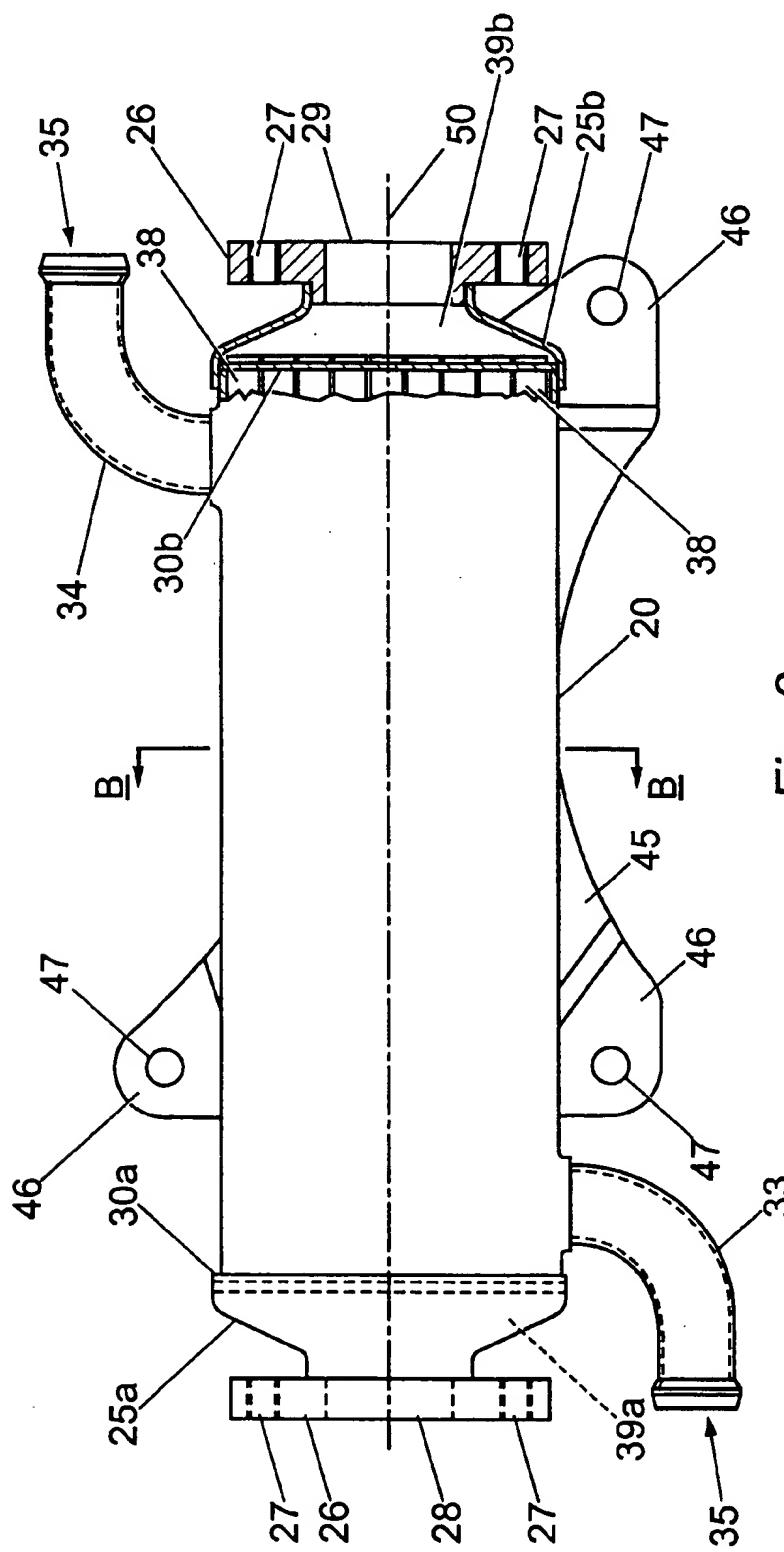


Fig. 2

3 / 3

